

TREE COVER DIAGNOSIS OF SÃO PAULO CITY

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ABSTRACT

Cities land use and landscape management are a big challenge for public sectors managers, who should search for low costs, efficient tools and scientific evidences that can improve these actions. This study aimed at comparing supervised classification of aerial images from 2002 and 2009, through MultiSpec W32, of tree cover diagnosis of São Paulo city. Land use indices and occupation were determined in selected sub regions of micro watersheds. It was possible to observe the metropolis growth dynamics and the urban forest adaptive changes. It was concluded that, in most regions, the exposed soil of 2002 was replaced by constructions in 2009, increasing the number of shadows on the region. The micro watershed with more trees, in both years, was the one of the Belini stream.

Keywords: GIS, MultiSpec, urban forest management, urban trees

DIAGNÓSTICO DA COBERTURA ARBÓREA DA CIDADE DE SÃO PAULO

RESUMO

Foi realizado um diagnóstico da cobertura arbórea da cidade de São Paulo, através de classificação supervisionada das imagens aéreas de 2002 e 2009 pelo MultiSpec W32, com fins comparativos. As sub-regiões escolhidas foram microbacias hidrográficas, nas quais foram determinados índices de uso e ocupação do solo, que permitem acompanhar a dinâmica do crescimento da Metrópole Paulistana e como a floresta urbana tem se adaptado a essas mudanças. Na maioria das regiões observou-se que o solo exposto de 2002 foi ocupado por construções em 2009, aumentando o número de sombreamento na região. A microbacia mais arborizada em ambos os anos foi a do Córrego Belini.

Palavras-chave: SIG, MultiSpec, manejo da floresta urbana, arborização urbana

INTRODUCTION

The increase in space consumption and the disordered growth of cities contribute to the green areas reduction and the degradation of life quality (LOMBARDO, 1990).

Urban forest is an important agent in the climate improvement because it increases humidity and reduces the temperature, avoiding heat islands and reducing pollution as it intercepts the particulate material and the stomata absorb the air pollutants, in addition to the aesthetics function (BONAMETTI, 2003).

Remote sensing and geoprocessing techniques are important to obtain information regarding the urban forest visualization and quantification, being an economical and efficient method that allows a general view of the studied regions (XIAO et al., 1999). In addition, it is possible to get information on the urban forest, such as free space and leaf area indices, used to model the benefits generated by it (NOWAK et al., 1996).

São Paulo city total area is 1,523 km², from which 760 km² correspond to green areas. However, this area is not divided into areas of gardens, tree plantations, parks, squares and conservation areas, but rather as total plant area (MOREIRA et al., 2007).

In this study, the city of São Paulo was divided according to the watersheds present in each region, which objective was to quantify and compare the urban forest in the years of 2002 and 2009.

MATERIALS AND METHODS

São Paulo is the biggest city in Brazil, with a population of 11.253.503 people. It is located in 23°32'0" S and 46°37'0" W, with an extension of 1,521 km² and average altitude of 860 meters (IBGE, 2013; CEPAGRI, 2013). The city has dry winter and hot summer, a Cwa climate type according to the Köppen-Geiger classification (KOTTEK et al., 2006).

It was studied the regions covered by the following watersheds: Aclimação; Anhangabaú; Belini; Branca; Cassandoca; Corujas; Curtume; Luz; Fortunato Ferraz; Glicério; Iguatemi; Morenguiho; Parque da Móoca; Sapateiro; Saracura; Tiburrinho; Uberaba; Verde I; Verde II; Dreno do Brooklin; Pacaembú; Traição; and Vinte e Três de Maio.

In order to carry out the study, images from Ikonos satellite of the year 2002 and images from Quickbird satellite of the year 2009 were used, both in the geotiff format, with squares of 5 km x 5 km and four bands: NIR (near infrared, that highlights the vegetation); Green; Blue and Red.

Following Silva Filho (2006) methodology, the satellite images were classified through the MultiSpec 3.2 free software. In the classification, five Training samples and five Test samples were prepared, totaling ten samples for each class. The watersheds regions image elements were classified according to the following classes: background; tree cover; lawn; exposed land; asphalt; shade; river/lake; pool; light roof; dark roof; gray roof; and ceramic roof.

Also, in the MultiSpec 3.2 software, the image classification statistical analysis was performed using the Kappa index, which indicates when some class presents pixels misclassified. This index ranges from 0.01 to 0.99, and the closer to 1.0 the more accurate the analysis.

It was accepted only thematic maps resulting in Kappa values equal or above 81%, which accuracy is considered almost perfect from Landis & Koch (1977) evaluation.

In order to analyze the accuracy of the supervised classification the Kappa index is widely used, since it includes all the elements of the error matrix (CONGALTON, 2001). The formula for obtaining the index was described in Landis & Koch (1997).

To evaluate the classification accuracy, omission and commission errors were analyzed, which equations were demonstrated in Ferreira et al. (2007). It was analyzed the result obtained from the subtraction between the omission and commission errors of the 100% that were tabulated.

And finally, to investigate whether major changes happened in urban space from 2002 (Ikonos satellite image) to 2009 (Quickbird satellite image), the percentages of thematic classes and scatter plots in Excel software were compared to analyze possible correlations between the years, through determination coefficient (R^2), that demonstrates how much of the total variation is common to the set of analyzed elements (CONTI, 2009). It varies from 0 to 1, the closer to 1 the greater the correlation between the variables (BAESSO & SOUZA, 2010).

RESULTS AND DISCUSSION

Omission and commission errors analysis are detailed in Table 1. The results indicate that occur a minimum percentage of error, which validates tree cover and lawn classification.

The classes classification results under discussion are presented in Table 2.

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Table 1. Omission and Commission percentage of tree cover and lawn supervised classification from Ikonos and Quickbird satellite images (São Paulo, SP, 2013).

Watersheds	Classes							
	Tree cover (%)				Lawn (%)			
	IKONOS (2002)		QUICKBIRD (2009)		IKONOS (2002)		QUICKBIRD (2009)	
	Omission / Commission		Omission / Commission		Omission / Commission		Omission / Commission	
Aclimação	99.3	99.8	98.3	98.5	100	92.3	99.1	97.6
Anhangabaú	97.1	74.5	100	99.5	63.3	92.6	97.6	100
Belini	98.4	99.0	97.6	99.4	97.9	96.7	98.4	93.8
Branca	93.2	78.5	94.0	99.5	85.4	95.4	99.4	91.0
Cassandoca	98.1	97.6	98.1	96.8	93.4	90.9	91.6	95.2
Corujas	99.0	98.5	97.6	97.7	99.1	95.1	98.2	97.3
Curtume	85.5	97.4	100	100	98.2	89.6	100	100
Luz	98.1	99.2	98.9	100	97.7	93.9	99.7	85.9
Fortunato Ferraz	98.8	99.7	97.1	99.7	99.3	97.6	99.4	92.5
Glicério	98.9	95.9	80.7	99.7	98.9	98.6	99.6	48.8
Iguatemi	96.8	99.7	100	100	100	87.0	100	100
Morenguinho	99.4	97.7	100	98.2	97.9	98.9	97.4	100
Parque Mooca	90.5	79.1	100	100	56.7	75.5	100	100
Sapateiro	100	100	98.6	97.4	100	100	96.8	98.3
Saracura	100	100	99.2	99.2	100	100	98.9	98.3
Tiburrinho	100	100	98.3	98.1	100	100	97.1	94.8
Uberaba	93.5	100	96.5	100	99.1	88.1	100	98.5
Verde I	99.0	100	98.6	98.4	100	97.2	95.5	95.8
Verde II	97.9	98.3	99.0	99.7	87.9	96.6	99.4	92.1
Dreno Brooklin	100	92.4	96.5	96.8	99.2	100	99.5	99.0
Pacaembú	97.7	100	99.6	97.9	100	98.5	98.1	99.6
Traição	93.0	99.0	98.9	90.5	96.1	71.8	96.6	99.6
Vinte e três de maio	98.5	90.2	96.1	88.2	64.9	92.4	93.5	97.9

Table 2. Tree cover, lawn, light exposed land, dark exposed land, shade and dark roof percentages of the watersheds from Ikonos (2002) and Quickbird (2009) satellite images (São Paulo, SP, 2013).

Watersheds	Tree cover (%)		Lawn (%)		Light exposed land (%)		Dark exposed land (%)		Shade (%)		Dark roof (%)	
	2002	2009	2002	2009	2002	2009	2002	2009	2002	2009	2002	2009
Aclimação	11.4	15.4	2.3	1.6	3.6	0.0	4.4	0.0	9.9	14.1	12.5	15.9
Anhangabaú	10.0	10.3	3.6	1.4	3.4	0.5	9.4	2.4	25.2	27.7	5.1	10.6
Belini	23.7	30.8	6.4	1.7	5.9	15.1	6.9	0.0	4.3	7.3	25.6	12.7
Branca	12.4	17.8	4.7	6.7	4.8	3.5	13.3	12.4	7.8	10.9	13.1	10.6
Cassandoca	7.3	8.1	0.9	1.0	1.0	0.3	0.3	0.6	16.9	8.6	25.5	28.9
Corujas	15.0	22.6	7.1	3.7	6.3	0.0	7.4	0.0	10.5	13.2	8.1	18.4
Curtume	7.6	9.3	8.1	4.2	1.9	0.0	3.0	7.1	8.4	6.5	19.7	22.1
Luz	6.3	6.4	1.3	1.1	3.4	0.8	1.8	6.7	13.6	29.8	3.5	14.6
Fortunato Ferraz	12.3	21.7	10.6	3.1	1.6	3.5	6.0	0.0	8.0	4.6	16.8	23.3
Glicério	6.3	4.8	1.7	6.2	1.6	5.6	16.3	0.0	11.2	25.3	12.8	24.5
Iguatemi	18.7	21.9	4.7	1.1	6.8	0.0	5.2	0.0	16.1	37.2	15.9	9.1
Morenguinho	18.6	13.1	3.6	3.9	2.8	14.7	0.0	0.0	13.1	23.8	8.9	27.3
Parque Móoca	10.7	6.6	3.2	0.5	9.9	0.0	6.8	0.0	8.9	15.8	4.7	13.2
Sapateiro	22.7	24.0	2.1	3.5	0.9	1.4	4.1	0.7	6.4	15.6	11.9	18.9
Saracura	7.9	12.3	0.1	0.7	0.0	0.0	0.0	0.0	15.7	29.8	30.1	24.2
Tiburrinho	17.0	15.0	0.3	1.9	1.6	0.0	0.0	0.0	12.8	5.8	14.3	8.2
Uberaba	17.1	9.1	0.2	3.7	2.6	1.5	0.0	3.7	10.5	26.3	24.7	11.7
Verde I	14.9	12.8	0.3	3.5	2.1	6.7	0.0	0.0	6.6	19.5	18.1	15.5
Verde II	21.8	26.8	0.6	1.3	2.7	0.3	0.0	1.3	7.1	18.2	23.4	19.3
Dreno do Brooklin	3.7	18.7	8.7	3.8	2.0	0.0	37.8	0.0	6.5	12.4	6.0	14.6
Pacaembú	12.7	22.0	17.2	1.8	0.0	2.1	9.7	15.3	10.5	17.5	6.2	10.9
Traição	11.9	11.8	0.3	8.4	4.2	1.9	36.6	4.6	4.7	11.0	4.2	21.0
Vinte e três de maio	13.3	9.4	4.1	5.1	0.0	0.0	0.0	0.0	12.7	24.0	15.8	32.6

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With these analyses, it was possible to do scatter plots (Figure 1 and 2). Figure 1 shows a determination coefficient of 0.43, which means there are 43% correlation between the variables, considered low, and indicates a change in tree cover between 2002 and 2009 in São Paulo city despite showing a tendency to positive correlation.

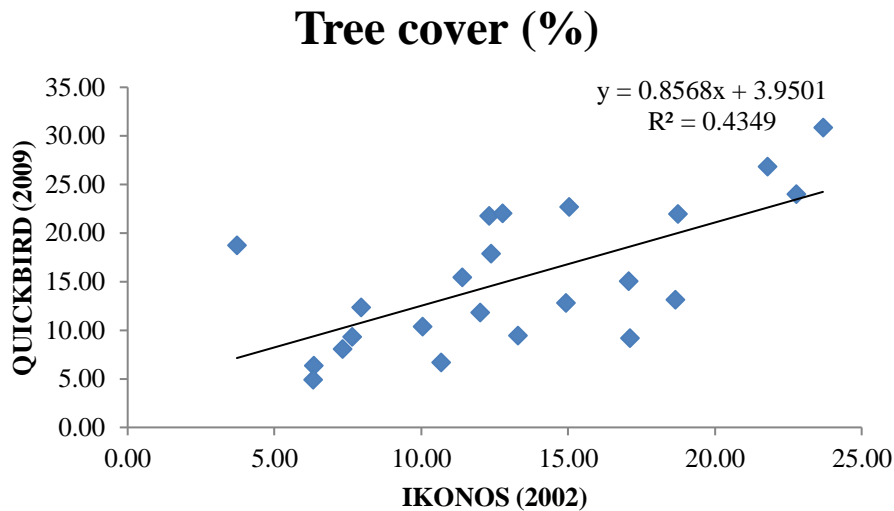


Figure 1. Tree cover percent scatter plots in 2009 and 2002 (São Paulo, SP, 2013).

Analyzing the lawn percentage correlations between 2009 and 2002, the R^2 value of 0.0003 (Figure 2) reveals a low value association, demonstrating an even greater change in lawn areas after seven years, without tendency to correlation values. Comparing it to the tree cover R^2 value, it is possible to affirm that lawn areas are easier to be occupied and modified than areas with trees, which have their management protected by law.

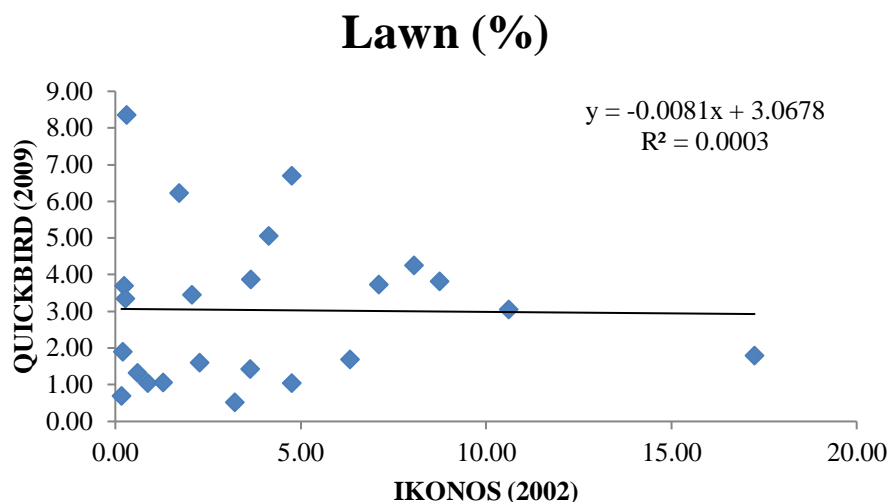


Figure 2. Lawn percent scatter plots in 2009 and 2002 (São Paulo, SP, 2013).

The watersheds description, classes percentage changes from 2002 to 2009 and its possible causes are shown below:

- Aclimação

Tree cover increased 4%, the lawn area reduced 0.7% and exposed soil was totally reduced in 2009 (Table 2). It is suggested that exposed soil area gave way to the trees.

- Belini

An increase of 7.1% in tree cover and 4.6% lawn reduction (Table 2) suggests tree occupation in lawn areas.

- Branca

An upgrade of 5.4% in tree cover (Table 2) can be explained by trees growth after seven years and the presence of clouds blocking part of the image of Ikonos satellite (2002) that are absent in Quickbird satellite images (2009).

- Corujas

Tree cover increased 7.6% while lawn reduced 3.37% (Table 2), the hypothesis are that trees have grown on lawn areas and the clouds presence in Ikonos satellite image (2002).

- Fortunato Ferraz

There was an increase of 9.4% in tree cover, a decrease of 7.5% of lawn and 6% in dark exposed land (Table 2), probably due to trees extent on these areas.

- Morenguinho

It was observed a decrease of 5.5% in tree cover that is probably related to the increase of 18.4% of dark roof and 10.6% of shade (Table 2) that occupied green areas. In cities vertical occupation it is normal that shadows increase, together with roofs due to the large buildings structures (SOUZA, 1994).

- Saracura

It was observed an increase of 4.4% in tree cover and 0.5% in lawn area in contrast to the decrease of all others classes (Table 2).

- Córrego Uberaba

A decrease of 7.9% in tree cover and 1.2% in light exposed soil in combination to an increase of 3.4% in lawn area and 16.1% in shade (Table 2) suggests an intensive land use change in this area.

- Córrego Verde II

Tree cover and lawn had a growth of 5.0% and 0.7%, respectively, which may be related to a 2.4% light exposed soil decrease (Table 2).

- Dreno do Brooklin

There was an increase of 15% in tree cover and a reduction of 4.9% in lawn area (Table 2) probably because of tree growth, pruning, planting seedlings and others. It is necessary to consider that occurred a slight confusion between these classes due to Ikonos satellite image resolution.

- Pacaembú

Tree cover increased 9.2% while lawn area had a reduction of 15.4%, which may have been occupied by dark exposed soil, which increased 5.6% (Table 2). There was also a confusion between tree cover and lawn classes in the Ikonos satellite image.

- Traição

Dark exposed soil had an intense reduction of 31.9%, because it has probably taken by lawn areas that grew 8% (Table 2).

Analyzing the total area of São Paulo city, while 125% of exposed soil decreased from 2002 to 2009, roofs and shadows show a growth of 122.4% and 157.7% (Table 2), respectively, which means that exposed soil of 2002 may have been occupied by buildings in 2009, which we can see in Figures 3, 4 and 5.

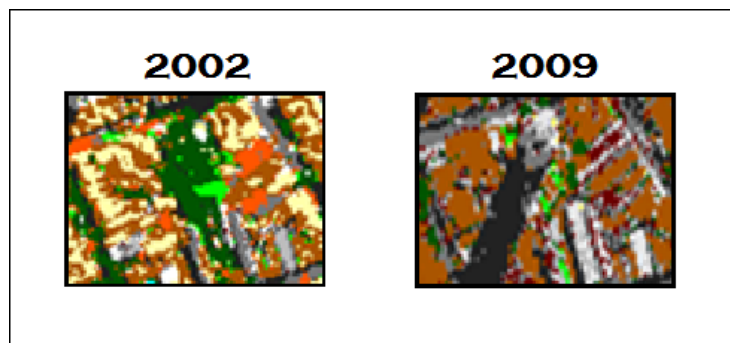


Figure 3. Exposed soil area in 2002 occupied by roofs and a building in 2009 in the Branca watershed (São Paulo, SP, 2013).

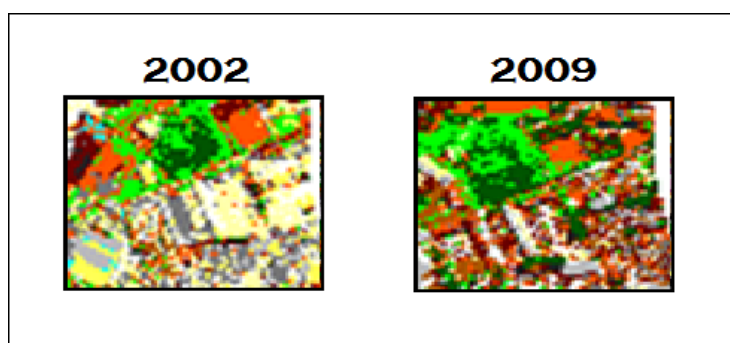


Figure 4. Exposed soil area in 2002 occupied by ceramic and metallic roofs in 2009 in the Tiburrinho watershed (São Paulo, SP, 2013).

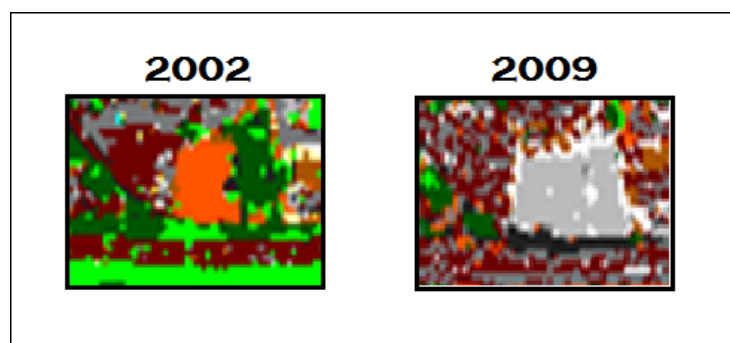


Figure 5. Exposed soil, trees and lawn areas in 2002 occupied by constructions in 2009 in the Parque da Mooca watershed (São Paulo, SP, 2013).

The watershed with a higher tree cover is Belini, both in 2002 and in 2009, followed by Sapateiro and Verde II in 2002 and by Verde II and Sapateiro in 2009 (Table 3). On the other hand, those with lower tree cover were Dreno do Brooklin (2002) and Glicério (2009), according to Table 3.

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Table 3. Watersheds ranking according to tree cover percentage in the Ikonos (2002) and Quickbird (2009) satellite images (São Paulo, SP, 2013).

Ikonos satellite (2002)			Quickbird satellite (2009)		
Ranking	Watersheds	Tree cover (%)	Ranking	Watersheds	Tree cover (%)
1°	Belini	23.68	1°	Belini	30.85
2°	Sapateiro	22.77	2°	Verde II	26.83
3°	Verde II	21.79	3°	Sapateiro	23.98
4°	Iguatemi	18.73	4°	Corujas	22.64
5°	Morenguinho	18.65	5°	Pacaembú	22.03
6°	Uberaba	17.10	6°	Iguatemi	21.95
7°	Tiburrinho	17.05	7°	Fort Ferraz	21.75
8°	Corujas	15.02	8°	Dreno do Brooklin	18.73
9°	Verde I	14.92	9°	Branca	17.84
10°	Vinte e três de maio	13.28	10°	Aclimação	15.44
11°	Pacaembú	12.76	11°	Tiburrinho	14.99
12°	Branca	12.37	12°	Morenguinho	13.10
13°	Fort Ferraz	12.30	13°	Verde I	12.76
14°	Traição	11.99	14°	Saracura	12.34
15°	Aclimação	11.39	15°	Traição	11.78
16°	Parque da Móoca	10.68	16°	Anhangabaú	10.31
17°	Anhangabaú	10.05	17°	Vinte e três de maio	9.42
18°	Saracura	7.94	18°	Curtume	9.31
19°	Curtume	7.64	19°	Uberaba	9.14
20°	Cassandoca	7.31	20°	Cassandoca	8.06
21°	da Luz	6.33	21°	Parque da Móoca	6.62
22°	Glicério	6.30	22°	da Luz	6.36
23°	Dreno do Brooklin	3.72	23°	Glicério	4.88

The Dreno do Brooklin watershed, in seven years, presented a growth of 15.01% in tree cover, which is very expressive compared to other areas (Table 3). The tree cover percentages revealed a variation between 3.72% and 23.68% in 2002, and a variation between 4.88% and 30.85% in 2009 (Table 3).

São Paulo urbanization has intensely increased during that period and most areas were occupied by asphalt, which entails significant microclimate change. Urban forest has increased in several regions but it is still far from representing a minimal ideal index. It is necessary that the management sector responsible to these watersheds rethink their administrative actions and how they focus on protecting and increasing their green areas over the years.

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